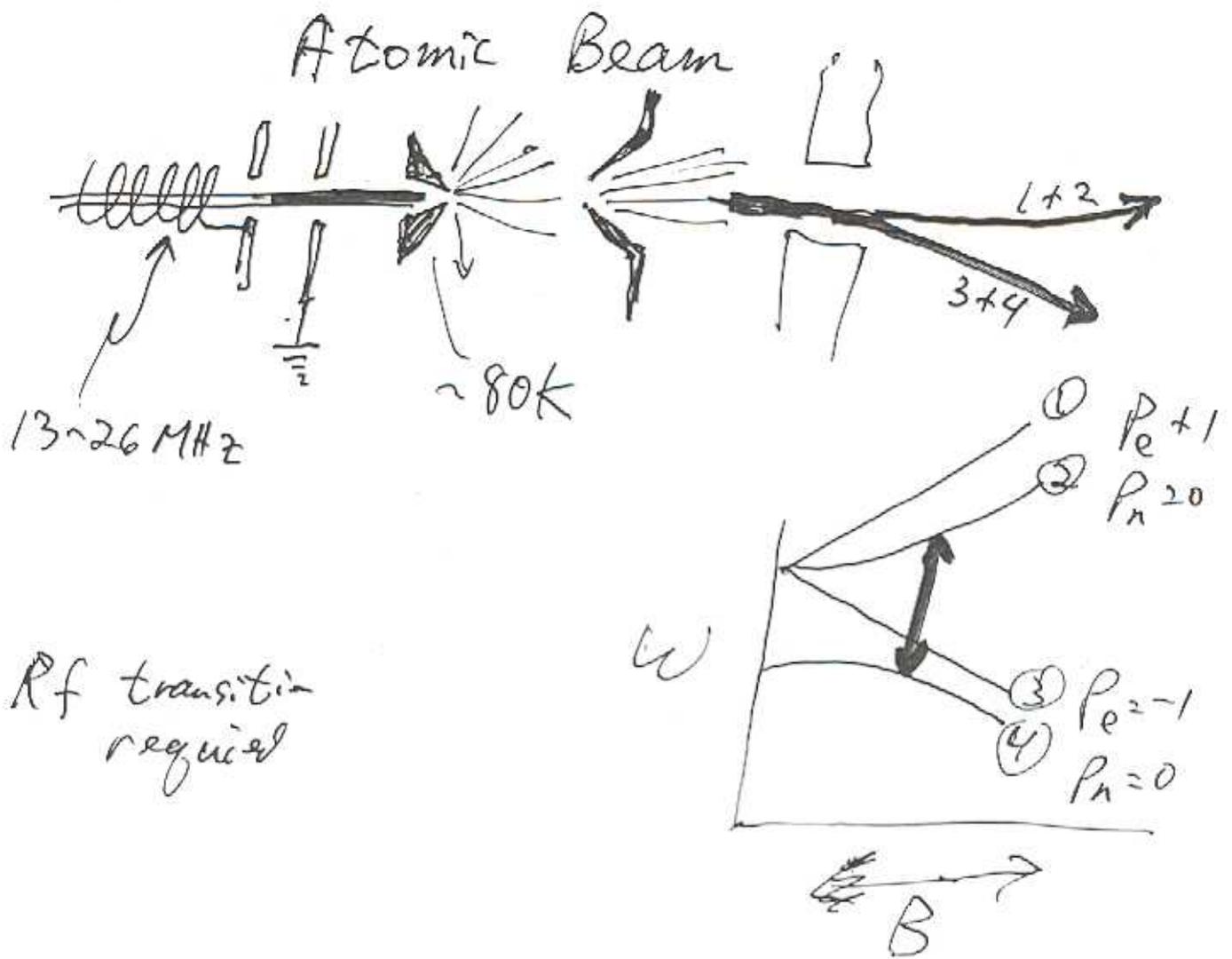


POLARIZED JET
DESIGN ISSUES AND OPTIMIZATION

WISCONSIN: T. Wise, P. Quin, W. Haeberli

MIT: H. Kolster

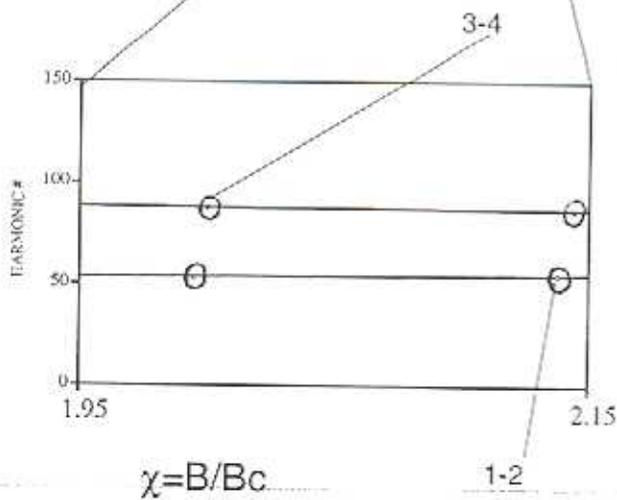
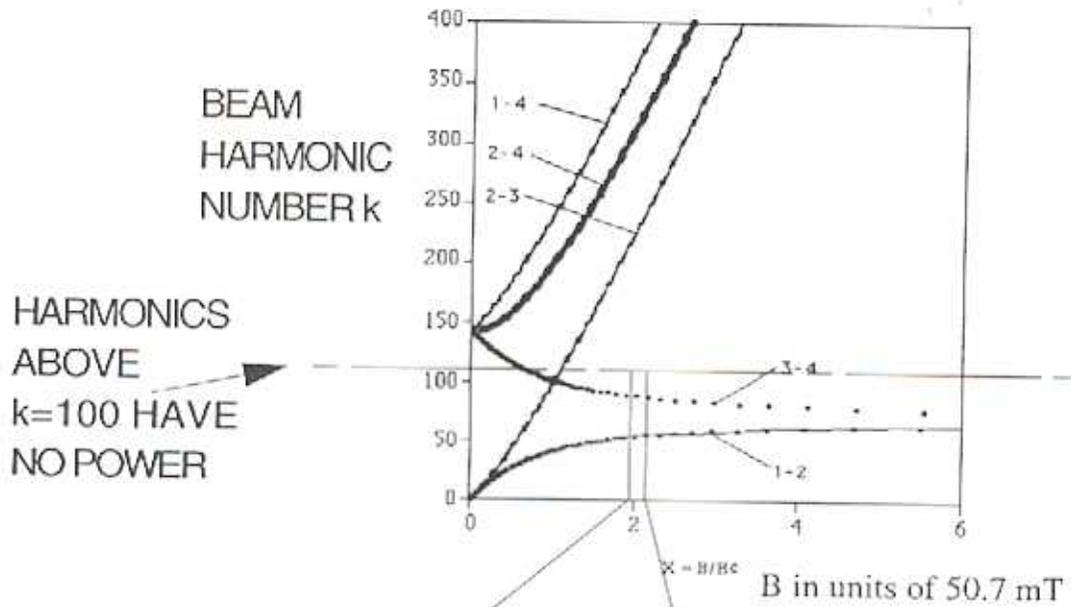


for use as calibration
 Need more than High intensity

we
 - need to know occupation #'s
 for the 4 substates.

TARGET REGION CONSTRAINTS

BUNCHFIELD RESONANCES



~32mm POLETIP GAP FOR CIRCULATING BEAM

- MINIMIZE MAGNETIC FIELD FOR LOW ENERGY RECOIL PROTONS
- VERTICAL ABS MUST ACCOMODATE 69" (1765mm) TO FLOOR

6-pole

MAGNET DESIGN

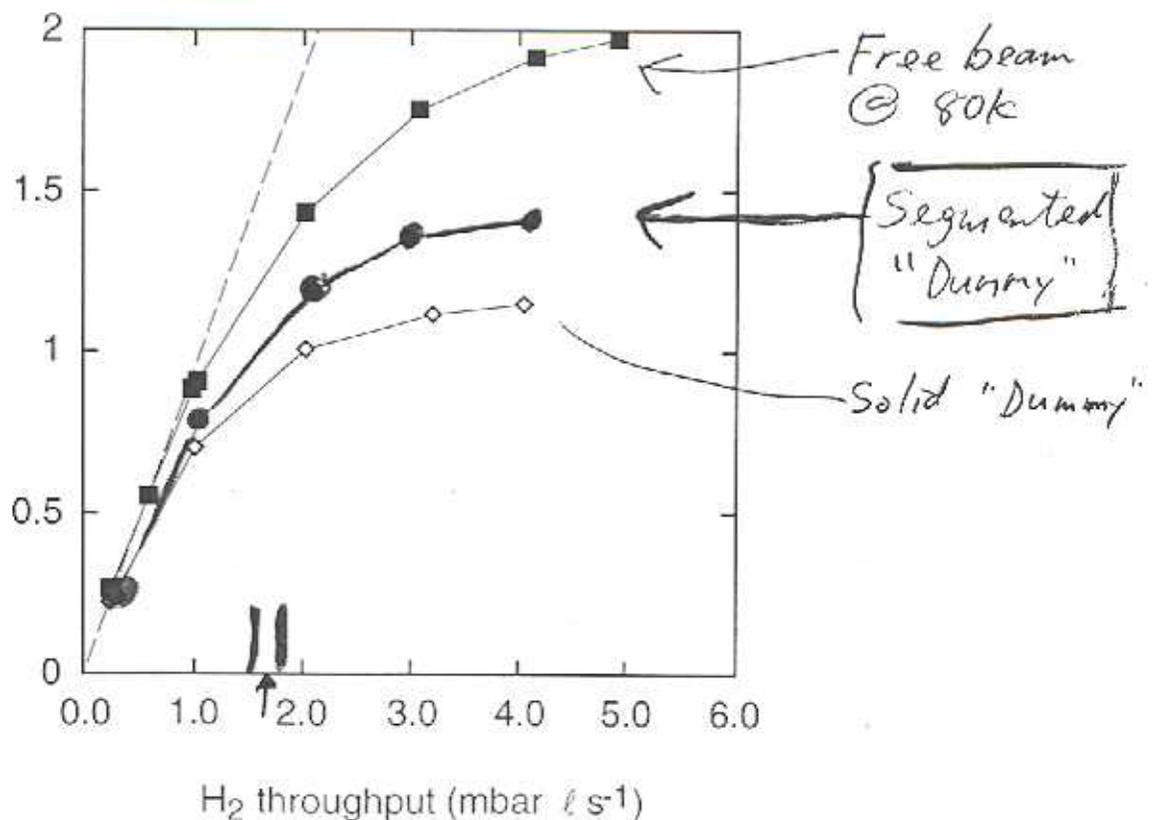
- Two codes used
- Both had errors
- Now they agree (two weeks ago)

One version picks random geometries and fills a 10 parameter space.

The other starts somewhere and performs a gradient search.

We added some factors to the output:

a) BEAM ATTENUATION -- gas scattering. (wisconsin 1992)

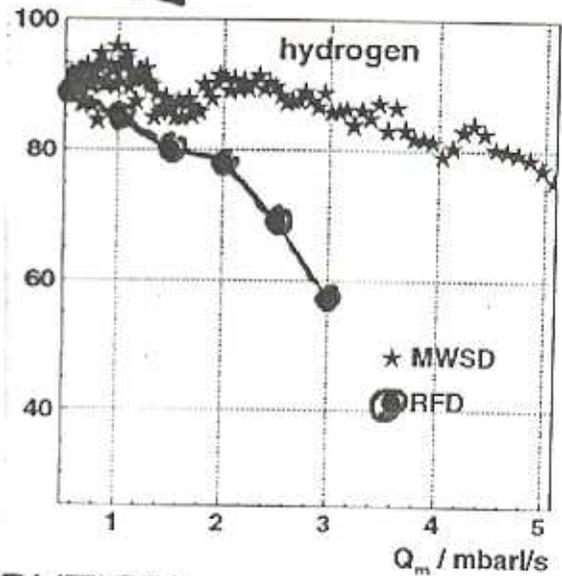
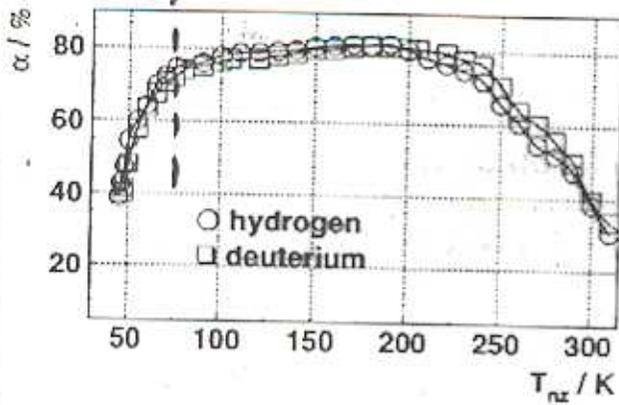


(b) DEGREE OF DISSOCIATION $\alpha = \#H / (\#H + 2 * \#H_2)$

Wisconsin 1992 and N. Koch thesis HERMES--1999

$$\alpha(Q, T) = \alpha(Q) * \alpha(T)$$

Assume Q, T dependence is separable



(c) START-VELOCITY DISTRIBUTION

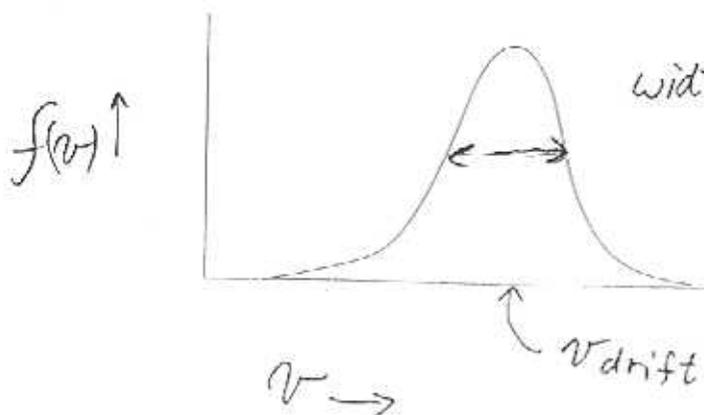
B. LORENTZ DIPLOMARBEIT, HEIDELBERG 1993

based on measurements with rf dissociated atomic beam

$$f(v) = 4 \pi v^2 \left(\frac{m}{2 \pi k T_{beam}} \right)^{\frac{3}{2}} \exp \left\{ - \left(\frac{m}{2 k T_{beam}} \right) (v - \underline{v_{drift}})^2 \right\}$$

$\underline{v_{drift}}$ depends on T_{nozzle} and Q (mbar liter/s)

$\underline{T_{beam}}$ depends on T_{nozzle} and Q (mbar liter/s)



$$v_{drift} \approx 1900 \text{ Meter/s}$$

$$T_{beam} \approx 20K$$

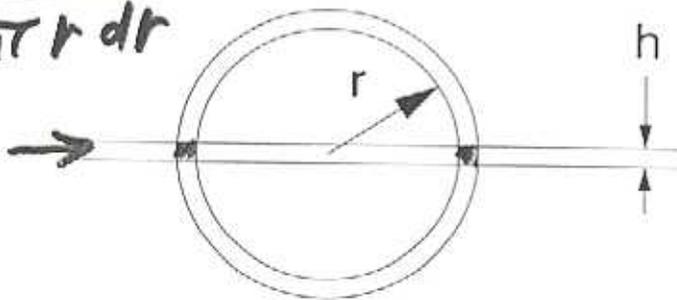
④ WE HAVE JET, NOT STORAGE CELL:

We give increased weighting to lower velocity atoms to account for their longer time in beam path.

$$\sum 1/v$$

⑤ RHIC BEAM IS LINE CHARGE: improve statistics of ray trace code by summing $1/r$.

$$\frac{2h dr}{2\pi r dr}$$



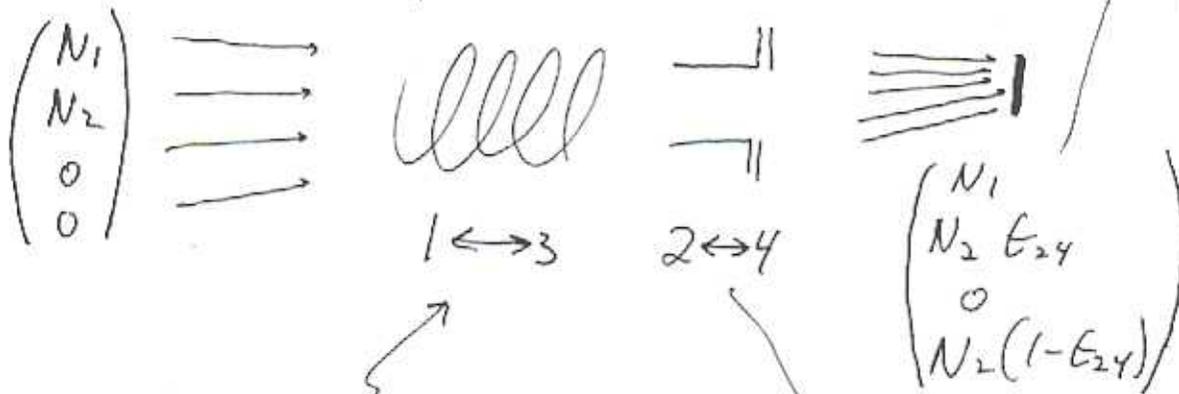
fraction of calculated trajectories at radius r that are seen by RHIC = h/r .
RHIC density prop. to $1/h$.

COMBINING ALL OF ABOVE
we optimize the function:

$$\tau(Q,T) = Q * \alpha(Q) * \alpha(T) * \{1 - A(Q,T)\} * \frac{\Omega}{N} * \sum_N \frac{1}{vT}$$

WHAT IS THE JET POLARIZATION?

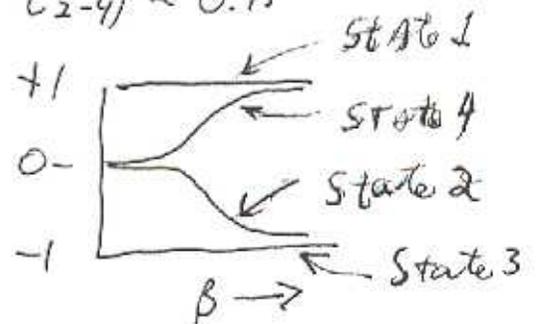
concept:



$$\text{efficiency} = (1 - \epsilon_{1-3}) \approx 0.95$$

$$(1 - \epsilon_{2-4}) \approx 0.95$$

EXAMPLE above 1-3 is off
2-4 is on.



State 1 polarization $Q_1 = 1$

State 2 " $-a \equiv Q_2 = \frac{-\chi}{\sqrt{1+\chi^2}} \approx 0.9 @ \chi \approx 2$

$$Q_3 = -1$$

$$+a \equiv Q_4 = \frac{+\chi}{\sqrt{1+\chi^2}} \approx 0.9 @ \chi \approx 2$$

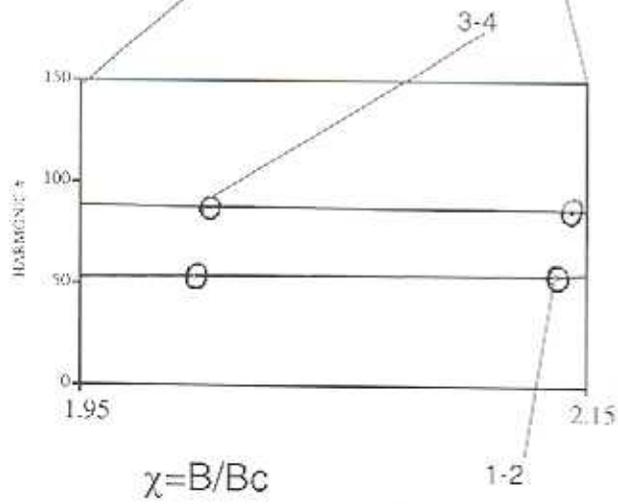
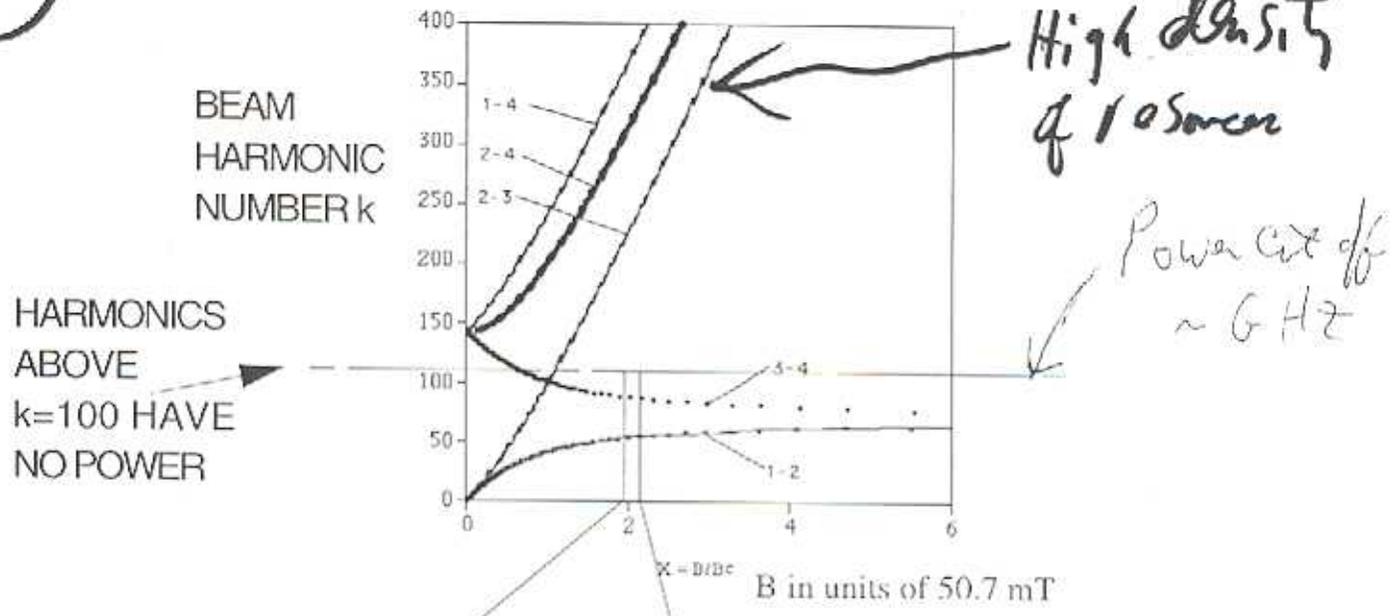
$$Q_{24} = \frac{N_1 - a \epsilon_{2-4} N_2 - 0 + a(1 - \epsilon_{24}) N_2}{N_1 + N_2}$$

$$Q_{13} = \frac{\epsilon_{13} N_1 - a N_2 - (1 - \epsilon_{13}) N_1 + 0}{N_1 + N_2}$$

TARGET REGION CONSTRAINTS

1

BUNCHFIELD RESONANCES



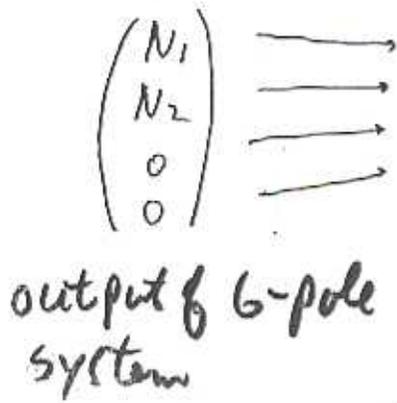
need $B_{target} > 1\text{ kG}$
 with $\Delta B/B = 6.3 \times 10^{-3}$
 low field
 \Rightarrow tighter
 uniformity

2
3
4

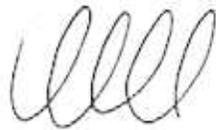
- ~32mm POLETIP GAP FOR CIRCULATING BEAM
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WHAT IS THE JET POLARIZATION?

concept:

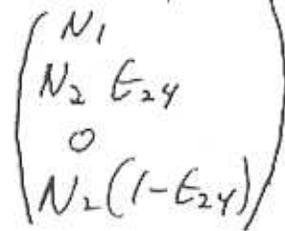
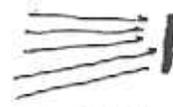


Rf transitions



$1 \leftrightarrow 3$

$2 \leftrightarrow 4$

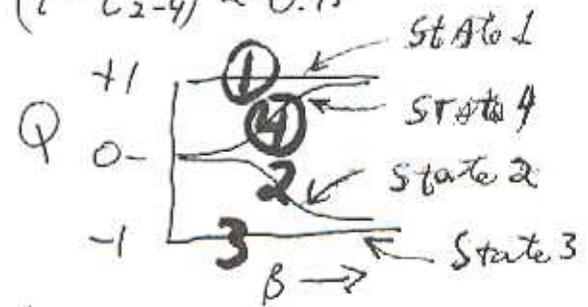


occupation numbers at the target.

efficiency = $(1 - \epsilon_{1-3}) \approx 0.95$

$(1 - \epsilon_{2-4}) \approx 0.95$

EXAMPLE above 1-3 is off
2-4 is on.



State 1 polarization $Q_1 = 1$

State 2 " $\boxed{-a} \equiv Q_2 = \frac{-\chi}{\sqrt{1+\chi^2}} \approx -0.9 @ \chi \approx 2$

State 3 " $Q_3 = -1$

State 4 " $\boxed{+a} \equiv Q_4 = \frac{+\chi}{\sqrt{1+\chi^2}} \approx +0.9 @ \chi \approx 2$

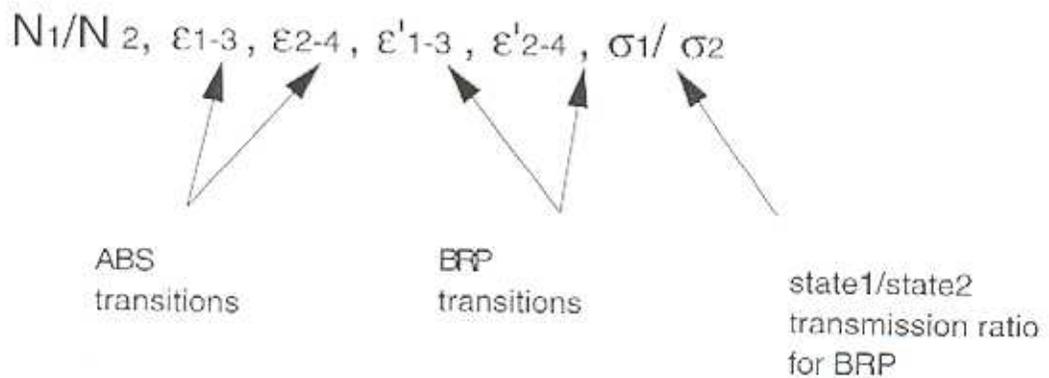
$Q_{24} = \frac{N_1 - a \epsilon_{2-4} N_2 - 0 + a(1 - \epsilon_{24}) N_2}{N_1 + N_2} \approx 1$

$Q_{13} = \frac{\epsilon_{13} N_1 - a N_2 - (1 - \epsilon_{13}) N_1 + 0}{N_1 + N_2} \approx -1$

NEED TO KNOW N_1/N_2 , ϵ_{1-3} AND ϵ_{2-4} .
(not easily done)

Our solution:

- 1) Add two additional rf transitions and separation magnets.
- 2) Completely remove rejected states (3,4) at each stage by use of on-axis beam blockers.
- 3) Run multiple combinations of Rf transitions to generate 10 intensity measurements and solve for five unknowns.



present BRP solution

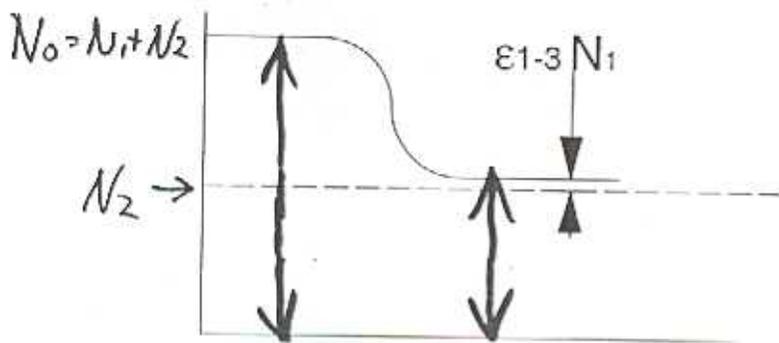


*Also very long.
same scale as ABS solution*

USEFUL WAY TO LOOK AT THE PROBLEM

BEAM INTENSITY AS RF1-3 IS
TURNED ON.

as seen by QMS. (Abs Polarimeter)



$$R_{13} = \frac{\epsilon_{13} N_1 + N_2}{N_0}$$

$$R_{24} = \frac{N_1 + \epsilon_{24} N_2}{N_0}$$

AFTER SOME ALGEBRA WE FIND CHANGE IN
POLARIZATION:

$$\Delta Q = Q_{1-3} - |Q_{2-4}|$$

$$\Delta Q = 2(1 + a - R_{1-3} - aR_{2-4})$$

N_1/N_2 does not effect ΔQ

$\langle Q \rangle$ does depend on
 N_1/N_2

Helpful Notation

$$\frac{N_1}{N_0} = \frac{1}{2} (1 + X_{abs}) \quad \frac{N_2}{N_0} = \frac{1}{2} (1 - X_{abs})$$

$$\frac{N_1}{N_2} = \frac{(1 + X_{abs})}{(1 - X_{abs})}$$

After some Algebra:

$$\langle p \rangle = \frac{P_{13} + P_{24}}{2} = \frac{-a \epsilon_{24} + \epsilon_{13}}{2} - X \frac{(a \epsilon_{24} + \epsilon_{13})}{2}$$

Error by ignoring $X_{abs} \neq 0$ is $\frac{-X(a \epsilon_{24} + \epsilon_{13})}{2}$

for $X = .03$ ($\frac{N_1}{N_2} = 1.06$)

$$\epsilon_{13} \approx \epsilon_{24} = 0.05$$

$$\text{Error in } \langle p \rangle = 0.0015$$

~~Not the entire story~~

BRP also has unequal state 1, state 2 transmission.

$$\text{i.e. } \frac{\sigma_1}{\sigma_2} \neq 1$$

Error from ignoring $\sigma_1/\sigma_2 \neq 1$:

$$\text{BRP Detector Sees } \frac{N_1 \sigma_1}{N_2 \sigma_2} = \frac{1+x}{1-x} \approx$$

$$\approx \frac{1+x_{\text{abs}} + x_{\text{brp}}}{1-x_{\text{abs}} - x_{\text{brp}}}$$

After some algebra, x_{abs} cancels

$$\boxed{|\text{Error } \Delta p|} = X_{\text{brp}} (\epsilon_{13} - a \epsilon_{24} + a - 1)$$

dominates.

$$\boxed{\Delta p \approx -0.1 X_{\text{brp}}}$$

$$\boxed{|\text{Error } \langle p \rangle|} = \frac{-X_{\text{brp}} (a \epsilon_{24} + \epsilon_{13})}{2}$$

$$\text{for } X_{\text{brp}} = 0.05 \left(\frac{\sigma_1}{\sigma_2} = 1.1 \right)$$

$$\epsilon_{13} \approx \epsilon_{24} = 0.04$$

$$a = 0.9$$

$$\text{Error } \Delta p \approx -0.005$$

$$\text{Error } \langle p \rangle = -0.002$$

Design conclusions:

1) although not critical we aim for $N_1/N_2 = 1$

2) BRP must transmit close to $\sigma_1/\sigma_2 = 1$ to avoid errors in target polarization measurement.

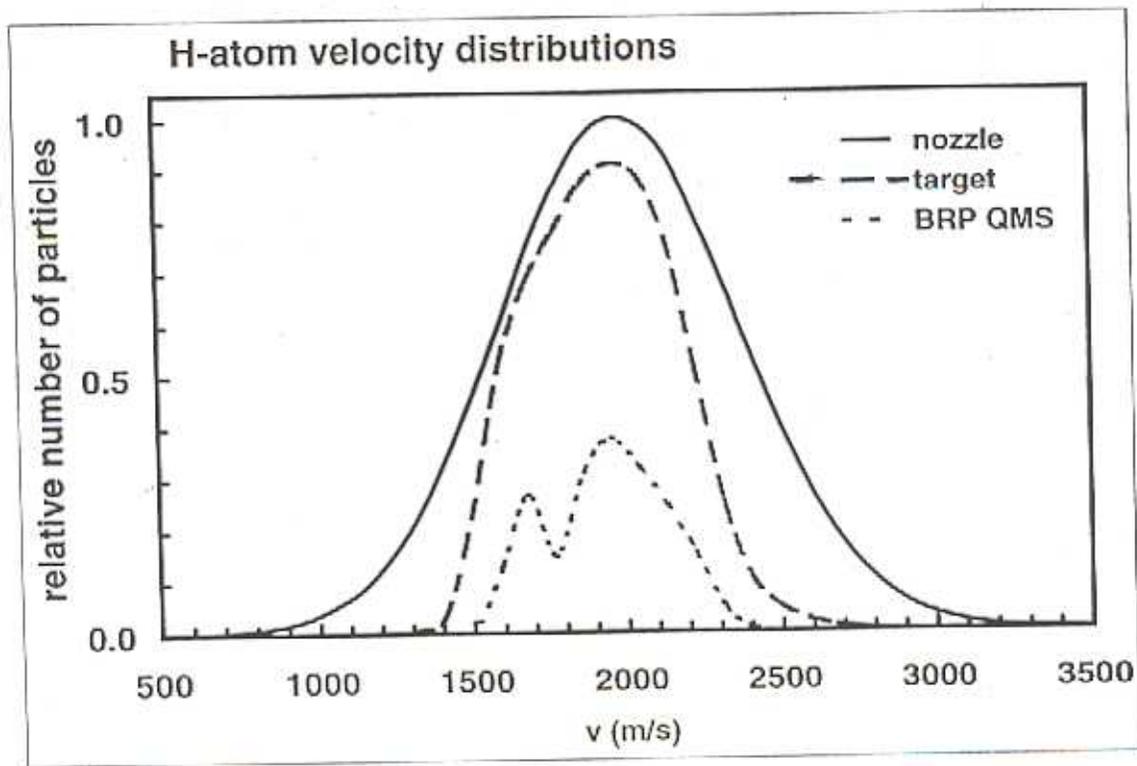
Ray tracing results

$$\frac{N_1}{N_2} \left(\varepsilon \frac{1}{r_0} \right) = 0.987 \Rightarrow X_{abs} = -0.007$$

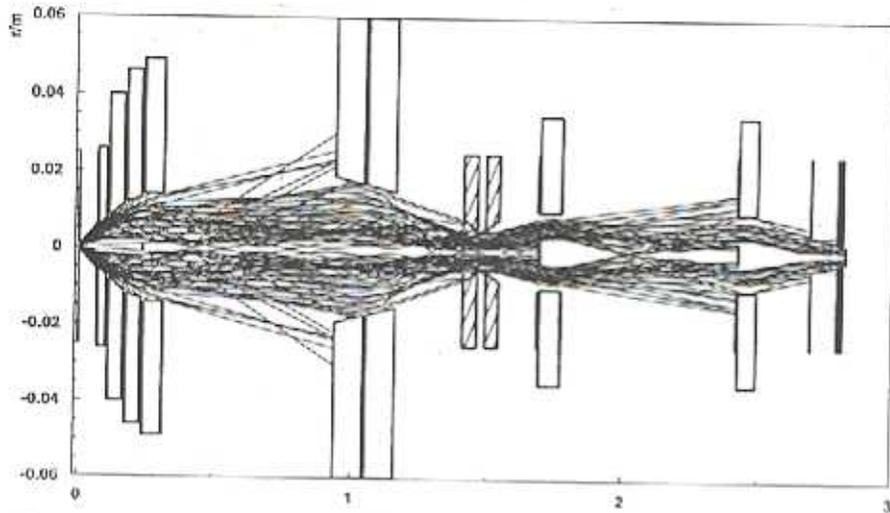
$$\frac{N_1 \sigma_1}{N_2 \sigma_2} \left(\varepsilon \frac{1}{r_0} \right) = .976 \Rightarrow X_{BRP} = -0.006$$

velocity dependent attenuator not accounted for yet.

Rejection of states 3, 4 better than 10^{-3}

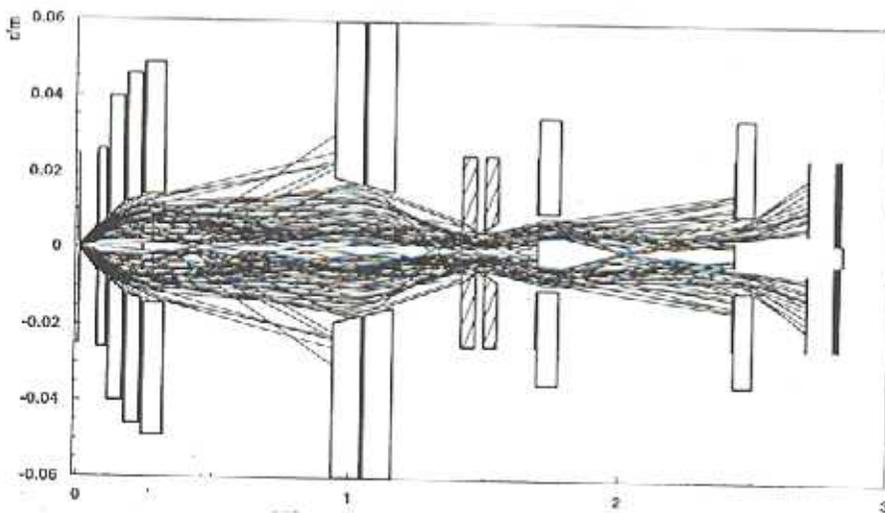


P108Q

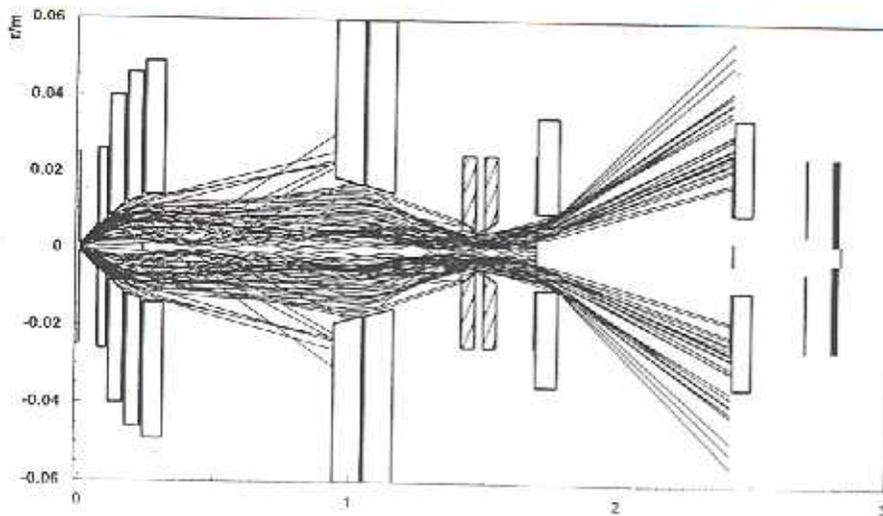


100 RAYS
 each ray is
 ~1% effect.

1, 1, 1
 No RF on



1, 1, 3 BRP
 RF 1 to 3
 ON

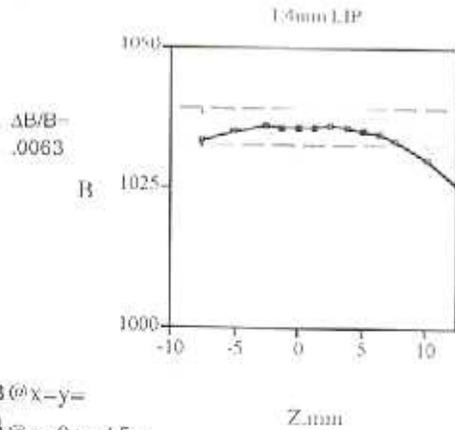
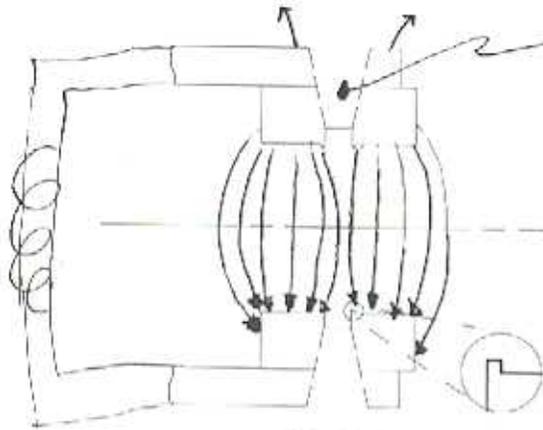


1, 3, 1
 Both ABS+BRP
 RF 1 to 3 ON

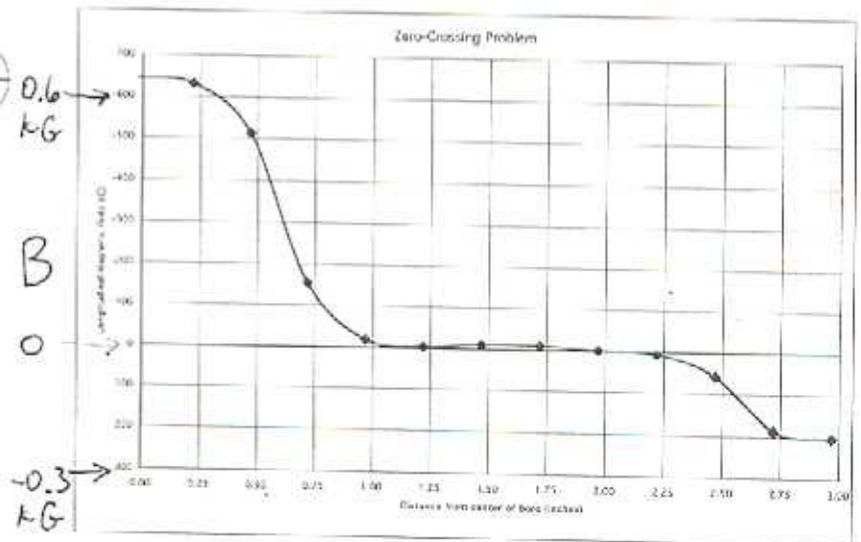
TARGET REGION MAGNET.

uniformity issue already solved

We have new problem--ZERO CROSSING



B@x=y=
B@x=0,y=±5m
m



Distance from Center →

we added ceramic magnet pellets to make transverse field.--only partially successful.

Computer modeling required.